Use of Hydrocoil in Small Aneurysms: Procedural Safety, Treatment Efficacy and Factors Predicting Complete Occlusion

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Summary

Coil technology has been directed to reduce recurrence rates and we have seen the introduction of trials comparing the efficacy of surface modified versus bare platinum coils (BPC). This article reports on one treatment strategy in the treatment of small aneurysms by the placement of Hydrocoil across the neck of the aneurysm. Procedural safety, treatment efficacy and factors which predict complete occlusion are evaluated.

We retrospectively identified a subgroup of small aneurysms treated over a four-year period. Analysis comparing aneurysms treated with Hydrocoil and BPC versus Hydrocoil alone was undertaken.

Eighty-five aneurysms were coiled; 62% with Hydrocoil alone, 38% in combination with BPC. At six-month follow-up, overall 50% were completely occluded, 39.5% had a neck remnant and 10.5% had a residual aneurysm. Complete occlusion was identified in 39% in the Hydrocoil and BPC group compared to 56% in the Hydrocoil alone group. In 56/76 (74%) cases analysed, Hydrocoil loop successfully bridged the neck of the aneurysm in which 38/76 (68%) of these were completely occluded at six-month follow-up. Thirteen procedure-related complications occurred.

Aneurysms treated with Hydrocoil alone resulted in fewer recurrences compared with a combination of Hydrocoil and BPC. These data suggest that the technique of positioning Hydrocoil at the neck of the aneurysm increases the probability of complete occlusion and is therefore a strong predictor of aneurysm occlusion. In our experience, this technique did not demonstrate an increased risk of intra-procedural rupture or thrombo-embolic complications compared to conventional embolization with BPC.

Introduction

Despite major technological advances, aneurysm recurrence after coiling remains a problem. Contemporary published series document retreatment after coiling in 17.4% [1,2]. Traditional wisdom considers that small aneurysms with small necks are less likely to recur, but more recent studies have reported a recurrence rate as high as 26% even in this selected group of aneurysms [3,4].

Although the re-haemorrhage rate after coiling during the follow-up period is low, caution and doubt persist over the correct treatment for the younger patient [5]. Furthermore, the relative infrequency of complete occlusion after aneurysm coiling dictates long-term follow-up with added financial and psychological burdens following endovascular treatment [6].

Developments in coil technology over the past decade have been directed at modifications intended to reduce recurrence rates and we have seen the introduction of randomised controlled trials comparing the efficacy of surface modified versus bare platinum coils (BPC) [2,7-8]. HELPS has reported a lower incidence of recurrence in aneurysms treated with Hydrocoil compared to treatment with BPC and gives persuasive evidence that surface modification with hydrogel achieves its intended purpose. Hydrocoil usage within HELPS was heterogeneous; the volume and proportion of Hydrocoil was not pre-specified and the optimum strategy for Hydrocoil incorporation during aneurysm treatment remains undefined. There is uncertainty whether benefit would be a consequence of enhanced volume-filling secondary to hydrogel expansion within the aneurysm as a packing/filling coil or whether there is benefit in having gel placed selectively at the neck of the aneurysm. During early clinical use there was appropriate anxiety about the safety of placing Hydrocoil at the neck of the aneurysm because of the theoretical possibility of gel swelling into the parent lumen. Although the HELPS trial found benefit from Hydrocoil, the nature of the effect remains undefined.

In our centre Hydrocoil has been used in the treatment of small aneurysms since 2004 and one treatment strategy includes the placement of Hydrocoil across the neck of a small aneurysm with support from a framing scaffold within the aneurysm sac. Usually this strategy requires the use of gel-coil from the start and requires a narrow-necked aneurysm. This is distinct from the normal strategy where a framing coil is used first and subsequently filled with gel-coil deployed centrally. The Hydrocoil is sized to the minimum diameter of the aneurysm and proprietary filling calculation software is used to guide the appropriate Hydrocoil length.

In this retrospective study, we have documented the effect of Hydrocoil in a homogeneous group of small aneurysms and offered some guide to effective hydrogel use.

Method

From our clinical database we retrospectively identified the subgroup of aneurysms treated with one, two or three coils, at least one of which was Hydrocoil, over a period of four years from January 2005 to December 2008 [9]. These were all first generation Hydrocoil, capable of swelling beyond the platinum wind rather than second generation Hydrosoft coils which expand only to the limit of the platinum wind. Eighty-two consecutive patients matching these criteria were identified with 85 small aneurysms and these were included in the study group. All patients had suffered subarachnoid haemorrhage at initial presentation and 69/85 aneurysms were treated acutely.

A single coil was used in 23 aneurysms, two coils in 38 aneurysms and three coils were used in 24 aneurysms. Hydrocoil alone was used in 53/85 (62%) aneurysms, and in combination with bare platinum coils in 32 (38%) aneurysms. Balloon remodelling was used in nine cases, and stent-assisted coiling was required in three cases. Coils were placed within an aneurysm in 84 procedures. In one patient a Hydrocoil was placed, but it migrated into the feeding artery of an arteriovenous malformation and the aneurysm was subsequently clipped as part of surgical treatment of the arteriovenous malformation.

The patients' age ranged from 30 to 77 years (mean age=53.5 years). Fifty-six (68%) out of the 82 patients identified were women and 26 (32%) were men. Each aneurysm was measured along three orthogonal diameters and a mean size calculated for the purpose of analysis. However, the diameter of the first coil for a procedure is determined by the smallest diameter of the aneurysm.

Six-month follow-up imaging was available in 76/85 (89%) aneurysms. During follow-up, three patients died from the initial haemorrhage and four were not investigated as a result of poor clinical outcome following subarachnoid haemorrhage. One patient moved overseas and was unavailable for follow-up imaging and one aneurysm was subsequently treated surgically. Of the 76 aneurysms with six-month follow-up imaging, catheter angiography was performed in 67 aneurysms, of these 60 also had an MRA (TOF) and in nine cases only MRA was available.

Angiographic occlusion of the aneurysm was scored according to the modified Raymond Roy classification [6]. For the purposes of this study a further category, 'interstitial filling' was included to describe a common appearance after treatment with Hydrocoil where there is coil at the neck with persistent contrast filling within the aneurysm between the interstices of the coils, but without exposure of the aneurysm wall to direct flow. Post procedure angiography and six-month follow-up imaging was assessed independently by two reviewers from patient archive communication system (PACS) workstations. Our routine follow-up protocol during the period of this study comprised digital subtraction angiography (DSA) with exact reproduction of working projections together with 'time of flight' MR angiography (MRA) at six months. In older patients or in cases of poor clinical outcome, follow-up may be limited to MRA. Post procedure and follow-up studies were assessed at different times in an attempt to minimize bias. Reviewer 1 (SV) was a neuroradiology trainee and reviewer 2 (AD) is a consultant interventional neuroradiologist with ten years' experience. 'Any discrepancy was assessed by a third reviewer (JM, consultant interventional neuroradiologist with 15+ years' experience) and a consensus decision was reached between JM and AD. Data were transferred to an Excel worksheet for analysis which was performed separately for all aneurysms and for those aneurysms treated with Hydrocoil alone.

Results

Aneurysm characteristics

Of the 85 aneurysms in the study, 69 were acutely ruptured, seven were elective re-treatments and nine were additional aneurysms. Of the nine additional aneurysms, three were treated acutely at the time of subarachnoid haemorrhage, whereas the remaining six were delayed treatments of additional aneurysms in patients with previous subarachnoid haemorrhage (Table 1).

Of the 69 patients with acutely ruptured aneurysms 38 were World Federation of Neurosurgical Societies (WFNS) grade 1, 13 were WFNS grade 2 and 18 were grade 3 or worse.

The mean aneurysm diameter ranged from 2.2 to 6 mm (average 3.4 mm). Eighty-one aneurysms measured 5 mm or less and 38 aneurysms were 3 mm or less. Seventy aneurysms were anterior circulation with anterior communicating (n= 29) and posterior communicating (n = 16) artery aneurysms being the most common (Table 2).

Aneurysm outcomes

Of the original 85 aneurysm treatments, two procedures were abandoned: in one case following coil migration and in the other following aneurysm rupture. Of the 83 aneurysms that were analyzed post procedure, occlusion grade was as follows: complete occlusion [Ray-

Table 1 **Indications for treatment**

Indication	Number
Acute subarachnoid haemorrhage – primary aneurysm	69
Acute subarachnoid haemorrhage – additional aneurysm	3
Previous subarachnoid haemorrhage – additional aneurysm	6
Previous subarachnoid haemorrhage – elective retreatment	7

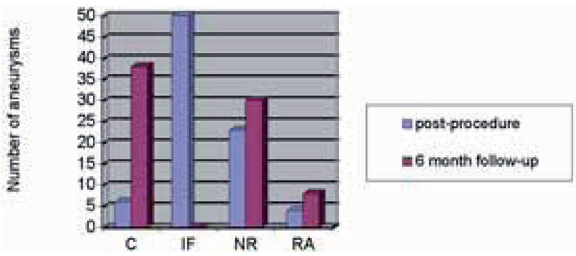
Table 2 **Location of aneurysms**

Location of Aneurysm	Number
Anterior communicating	29
Posterior communicating	16
Middle cerebral	12
Basilar tip	10
Internal carotid	9
Posterior inferior cerebellar	5
Anterior cerebral artery	2
Anterior choroidal artery	1
Pericallosal	1
Total	85

mond 1 or C] in six (7%), neck remnant [Raymond 2 or NR] in 23 (28%), residual aneurysm [Raymond 3 or RA] in four (5%) and 50 (60%) had interstitial filling [IF] within the coil-ball.

The 76 aneurysms with six-month imaging follow-up were analyzed with respect to filling volume, the type and numbers of coils used and if gel was present bridging the neck. At six-month follow-up imaging the aneurysm treatment grading overall was: complete occlusion in 38/76 (50%), interstitial filling in 0/76 (0%), neck remnant in 30/76 (39.5%) and residual aneurysm in 8/76 (10.5%) (Graph 1).

Graph 1 Occlusion grades post procedure and at six-month follow-up.



Filling volume

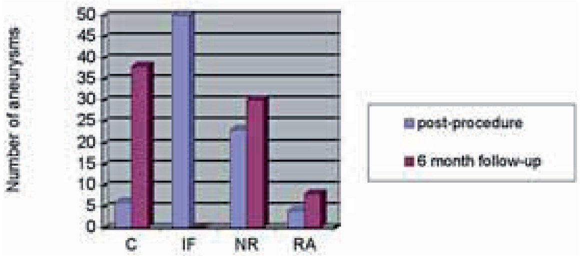
Theoretical filling volume based on the assumption of expansion of the hydrogel was calculated to be less than 100% in 37 aneurysms, and more than 100% in 39 aneurysms.

The distribution of occlusion grades on the follow-up imaging was similar in both groups and did not demonstrate a specific trend towards complete occlusion in either group (Pie chart 1).

Forty-eight (63%) of the 76 analysed aneurysms were treated with Hydrocoil alone. At six-month follow-up in this group, 27/48 (56%) were complete, 15/48 (31%) had neck remnants and 6/48 (13%) had residual aneurysms.

A comparison with the whole group is shown in Table 3 and Graph 2.

Graph 2 Comparison of Hydrocoil exclusive group with combined group at follow-up.



No correlation was observed between the size of the aneurysm or the number of coils used and the subsequent occlusion grade.

Gel at the neck

Of the 76 aneurysms analyzed, a Hydrocoil loop successfully bridged the neck in 56 (74%) cases at the end of the procedure. Of these aneurysms, 38/56 (68%) were completely occluded at six months, 14/56 (25%) had stable neck remnants and 4/56 (7%) had residual aneurysms. Hydrocoil was not seen at the neck in 20 (26%) aneurysms, and at six months 16/20 (80%) aneurysms were found to have neck remnants, 4/20 (20%) aneurysms had residual filling and no aneurysms had complete occlusion in this group (Pie Chart 2).

Of the 76 aneurysms where follow-up angiography was available, seven aneurysms demonstrated progression to a higher Raymond grade. Of these, three cases had moved from Raymond grade 2 to grade 3, three cases with interstitial filling moved to grade 3 and one case had moved from grade 1 to grade 2.

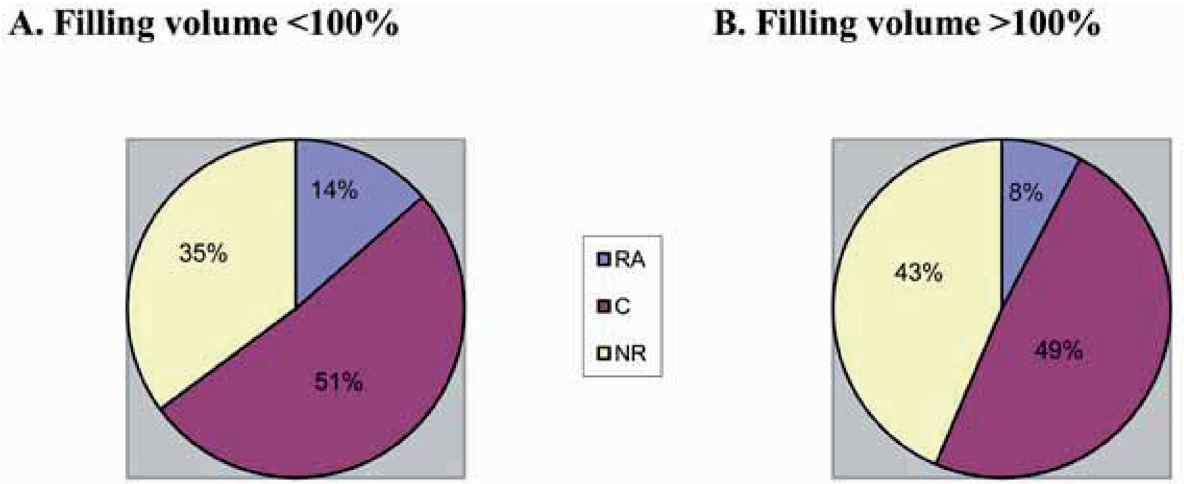
Procedural complications

Out of the 85 aneurysms treated there were 13 procedure-related complications overall. These included three (3.5%) intra-procedural ruptures, two (2.4%) coil protrusions albeit

Table 3 **Occlusion grades in Hydrocoil and bare platinum group versus Hydrocoil alone.**

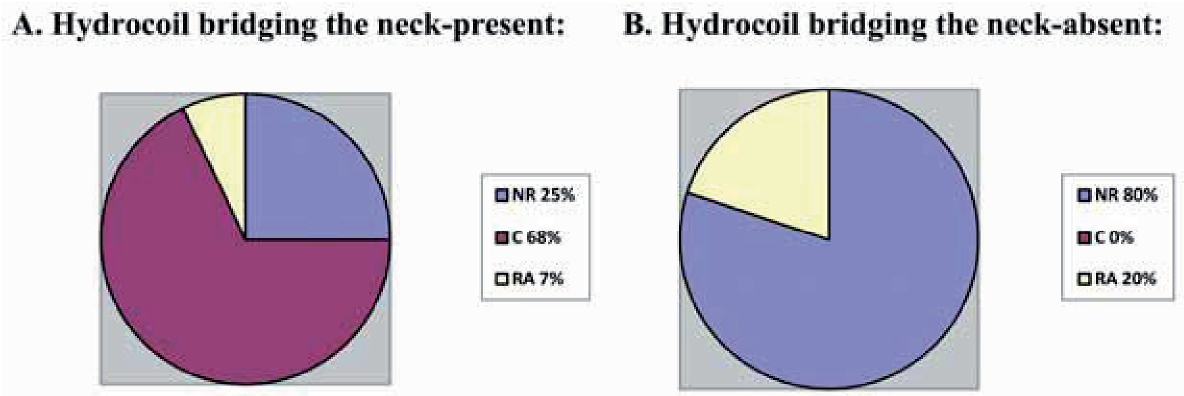
Occlusion grade	**Hydrocoil & bare platinum**	**Hydrocoil alone**
Complete	11/28 (39%)	27/48 (56%)
Neck remnants	15/28 (54%)	15/48 (31%)
Residual aneurysms	2/28 (7%)	6/48 (13%)

Pie Chart 1 Filling volume – correlation with occlusion grades at follow-up.



Abbreviation key: *C* - Complete occlusion; *IF* - Interstitial filling; *NR* - Neck remnant; *RA* - Residual aneurysm.

Pie Chart 2 Hydrocoil at neck – correlation with occlusion grade at follow-up.



with no obstruction to flow or clinical sequel, four (4.7%) thrombo-embolic complications and four (4.7%) femoral access complications (Table 4).

Table 4 **Procedure-related adverse events**

Adverse event	Number (%)
Thromboembolic	4 (4.7%)
Aneurysm rupture	3 (3.5%)
Coil protrusion	2 (2.4%)
Groin-related	4 (4.7%)

There were three procedural ruptures. In one case, a PICA aneurysm with the smallest diameter of 2.3 mm ruptured on attempting to place a 2 mm × 3 cm Hydrocoil and this was associated with a fatal outcome. The second rupture occurred during placement of a 4 mm × 10 cm bare platinum coil in an anterior communicating artery aneurysm measuring 4 mm × 3.3 mm × 3 mm. Emergency management consisted of rapid coiling with Hydrocoil. The third case demonstrated extravasation of contrast angiographically in a 3.9 mm × 3.6 mm × 3.5 mm anterior communicating artery aneurysm with the placement of a 3 mm × 6 cm Hydrocoil, but there were no clinical consequences.

Thrombo-embolic complications were seen angiographically in one case with thromboembolism into the right MCA prompting treatment with intravenous Abciximab. The patient was hemiparetic following the procedure with incomplete recovery at six months. One patient had transient neurological symptoms after the coiling procedure with full recovery within 24 hours. Two patients had small infarcts within an appropriate vascular territory on follow-up imaging with MRI but were clinically asymptomatic.

Vascular access complications occurred in four patients. Retroperitoneal haemorrhage occurred in one patient. A false aneurysm of the femoral artery developed in a further patient and this was successfully treated with thrombin injection. One patient, found to have iliac artery stenosis during the procedure, suffered external iliac artery dissection. This was treated effectively with balloon angioplasty and there were no clinical consequences following the procedure. Finally, one patient with a small groin haematoma was managed conservatively with complete resolution.

Re-treatments were performed in three out of the eight patients with residual aneurysm. One patient underwent surgical clipping, another was re-treated with coiling and the third was initially clipped and then required further coil treatment due to the development of a pseudoaneurysm complicating surgery. The remaining residual aneurysms were not appropriate for further treatment. The majority of neck remnants at the end of the procedure were stable on follow-up and were not treated.

Overall, there were four deaths among the patients studied. Following procedural rupture, one patient died shortly afterwards. A second patient died after two weeks due to vasospasm complicated by other medical problems. The third death occurred four weeks later secondary to multi-organ failure complicating subarachnoid haemorrhage. The fourth death occurred at ten months and although the exact cause of death remains uncertain, this might have occurred secondary to stent-related thrombosis and embolism.

Of the 72 patients reviewed at clinical follow-up (median of 12 months), ten cases (14%) had moderate to severe disability requiring at least some help with daily activities [Modified Rankin scale of 3 or more]. The MRS was less than or equal to 2 in 62 cases (86%).

Discussion

We have been using Hydrocoil for the treatment of aneurysms since October 2004 and participated in the HELPS trial. The potential advantages of Hydrocoil and preliminary reports of effectiveness of Hydrocoil compared to aneurysms treated with BPC led us to adopt its use where possible. Initially it was used in larger aneurysms but subsequently also in smaller ruptured aneurysms.

Small aneurysms require treatment with relatively few coils and represent a more homogeneous group to study possible effects of a specific coil. We therefore chose to analyse this subgroup of aneurysms to consider the safety and efficacy of Hydrocoil and to determine if there was a defined Hydrocoil 'effect' that might predict complete occlusion. Aneurysms treated with the second generation Hydrosoft coil were not included. We planned to examine any specific effect of the surface-modified coil employed in the HELPS study and therefore analysis was restricted to aneurysms treated with Hydrocoil.

Conventional coil treatment usually employs a larger diameter-framing coil followed by central filling likened to a Russian-doll. In an effort to reduce recurrence, our technique for the treatment of small aneurysms with Hydrocoil is to engineer positioning of a gel-coated loop or loops across the neck, supported by the intrasaccular coil scaffold, whether that is BPC or Hydrocoil. Hydrocoil is a challenging coil to use: the coil is stiffer and deployment is time-limited. If the coil is not fully deployed within four minutes, the coil may not be retrievable. Therefore, the operator needs to be confident that the gel-coil is small enough to fit into the aneurysm and remain stable within the aneurysm. The coil may not need much complexity if the neck is narrow and there is little concern regarding coil migration.

In our experience most problems result from oversizing the coil and we have found it imperative to size the first Hydrocoil to the *minimum* diameter of the aneurysm. Where platinum coils have already been placed in the aneurysm we generally size the Hydrocoil diameter 2 mm (rather than 1 mm) less than the previous coil. Oversizing the second coil may result in the stiffer Hydrocoil springing a loop of bare platinum into the parent vessel. We find proprietary 'filling calculation' software packages helpful to guide the length of Hydrocoil to be used, particularly in very small ruptured aneurysms where it may be possible to treat the aneurysm with a single coil.

This report demonstrates that it is possible to use gel-coated coils from the start of the aneurysm treatment. If Hydrocoil is used as the first coil and there is a delay in deployment, it is possible to retrieve the coil after gel expansion simply by withdrawing the microcatheter and coil en masse. The corollary of this observation would be that in a situation where the catheter position is precarious or the aneurysm was difficult to catheterize safely, a different coil strategy might be safer.

Results from this study reveal that the aneurysms treated with Hydrocoil alone resulted in fewer recurrences compared to those treated with a combination of Hydrocoil and BPC, mirroring the results from the HELPS trial.

This retrospective study was designed to investigate the nature of this Hydrocoil effect. One possible explanation is the fact that Hydrocoils are stiffer and less deformable than BPC. This may make them more resistant to compaction. Another possibility is that the gel promotes a healing reaction helping to stabilize thrombus within the aneurysm or possibly even endothelialization at the neck. For the reasons outlined above, the adoption of Hydrocoil for the treatment of small ruptured aneurysms appears to represent a significant advance in the treatment and demonstrates a reduction in recurrence rate compared to BPC. The study also looks at the rates of complete occlusion using the technique of positioning Hydrocoil at the neck of the aneurysm.

Our study reveals that when the neck has been covered with Hydrocoil there is a high probability of complete or stable occlusion: 68% of the small aneurysms at six-month follow-up were completely occluded, significantly more than aneurysms where Hydrocoil did not bridge the neck. Eccentric swelling of the gel, when the coil is placed at the neck may provide better occlusion at the inflow and it may also provide a framework for subsequent thrombosis and endothelialization to bridge the neck offering the opportunity for durable occlusion and a reduced rate of recurrence.

A simplistic hypothesis would be that the number of coils deployed and hence volume filling would influence the number of recurrences at follow-up. In this study we found no correlation between the theoretical calculated filling volume and complete occlusion. In our experience the technique of Hydrocoil placement in small, acutely ruptured aneurysms did not demonstrate an increased risk of intra-procedural aneurysm rupture or thrombo-embolic complications compared to conventional embolization with BPC and our figures are similar to other studies. The intra-procedural rupture rate with GDC coils ranges from 2.5% [10,11] to 5% [12], mirroring the complication rate found in this study (3.5%).

The most frequent complication related to aneurysm coiling is thrombo-embolism. The prevalence of thrombo-embolic events has been reported as ranging from 2.3% to 10.4% [13]. We observed four thrombo-embolic complications (4.9%), one resulting in hemiparesis which had not resolved at the six-month follow-up, one patient suffered transient neurological symptoms and two patients were found to have small infarcts on imaging that were clinically asymptomatic. Our figures represent the lower end of the spectrum for the rate of thrombo-embolic events and this supports the safety of using this technique when treating small ruptured aneurysms.

Conclusion

Our study demonstrates that using Hydrocoil alone results in fewer recurrences than a combination of Hydrocoil and bare platinum coils, and demonstrates that the technique of placing Hydrocoil at the neck is a strong predictor of aneurysm occlusion. These data support the hypothesis that the technique of deliberately placing gel at the aneurysm neck promotes occlusion with a reduction in recurrence rate.

The limitations of the study, however, are that it is retrospective and the number of patients included is not sufficiently large to undertake statistical analysis. Furthermore, the procedures were performed by experienced operators aware of the limitations and difficulties of Hydrocoil deployment and there may be a learning curve for those unfamiliar with handling gel-coils.

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